Dielectron Measurements by PHENIX using the HBD

Quark Matter 2012

Ermias ATOMSSA
For the PHENIX Collaboration

Stony Brook University

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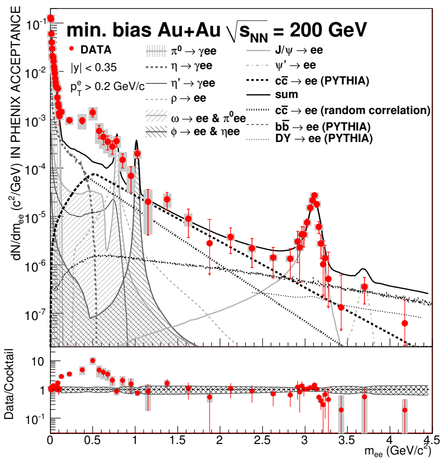
Outline

- Physics Motivation
- HBD detector
- Hadronic Cocktail
- p+p Result
- Au+Au Results

Dielectron Mass Spectrum

- Dileptons spectra carry abundant information about the *evolution* of the medium: They are created at all stages and do not interact strongly
- Low Mass Region
  - Modification of light vector mesons
    → Chiral Symmetry Restoration
  - Thermal photons
    → Temperature of the medium
- Intermediate and High Mass Region
  - Open heavy flavor
    → Heavy quark energy loss
  - Quarkonia
    → Quarkonium suppression
- Most striking observation is the x10 enhancement seen in the ≈ 150 MeV to 750 MeV compared to expectation from purely hadronic decays

Phys. Rev. C 81, 034911 (2010)



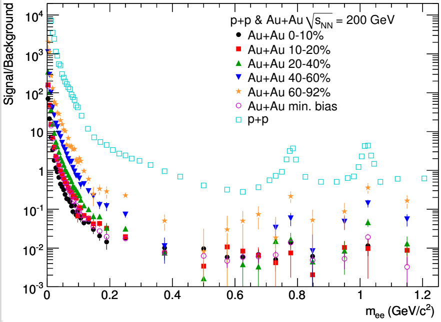
Challenges of the measurement

- Signal to background in PHENIX published measurement lowest in most interesting region
- Dominant source of background is combinatoric electron pairs from π^0 decays

$$\pi^0 \rightarrow \gamma e^+ e^-$$

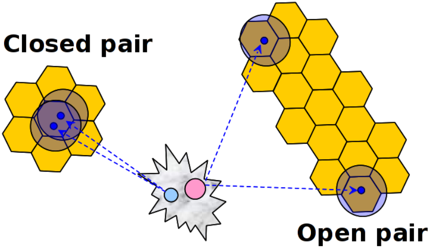
$$\pi^0 \rightarrow \gamma\gamma \rightarrow e^+ e^- e^+ e^-$$

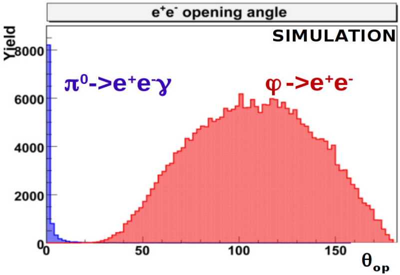
  that get separated by the magnetic field and only one leg is reconstructed
- Only way to identify such pairs is to tag them before they get separated by the magnetic field



Motivation for a Hadron Blind Detector

- Identification of partially reconstructed Dalitz and early conversion:
  - Measure charge before e^+e^- pair is separated by the magnetic field (Hence the requirement of field free region and change in magnetic field configuration from previous measurements)
  - Background electrons produce twice the signal of signal electrons
  - Hadron Blind Detector (HBD)





The Hadron Blind Detector

NIM A646 p35, 2011

HBD hardware

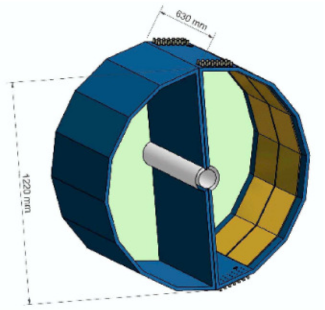
- Windowless Čerenkov Detector
- CF_4 - Radiator and Active gas
- Triple GEM signal multiplication
- CsI photo cathode, hexagonal pad readout
- 2.4% total radiation length

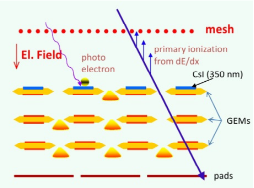
Hadron Blindness

- Čerenkov threshold for $\pi^{\pm} \approx$4 GeV
- Reverse bias operation to repel ionization from charged hadrons

Double rejection

- Near zero B-field up to GEMs
- Low mass pairs keep small opening angle and leave twice as much signal as single electrons





Expectation from Hadronic Decays

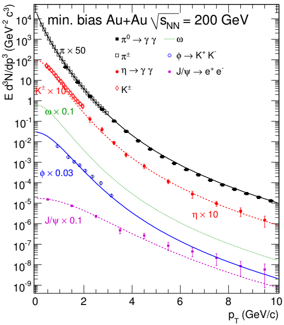
- Fit π^0 and $\pi^\pm$ spectra using Hagedorn function

$$E\frac{d^3}{dp^3} = \frac{A}{(e^{-(ap_T + bp_T^2)} + p_T/p_0)^n}$$

- For other hadrons: Use m_T scaling for shape

$$p_T \rightarrow \sqrt{p_T^2 + (m_h^2 - m_{\pi^0}^2)}$$

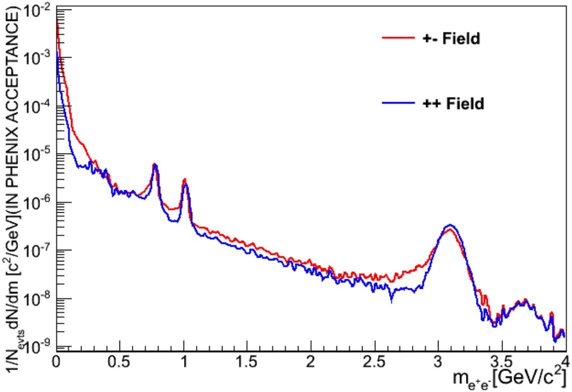
  fit to measured spectra for normalization
- The fits are done independently for each species and collision centrality



Changes from published cocktail (Phys. Rev. C 81, 034911 (2010))

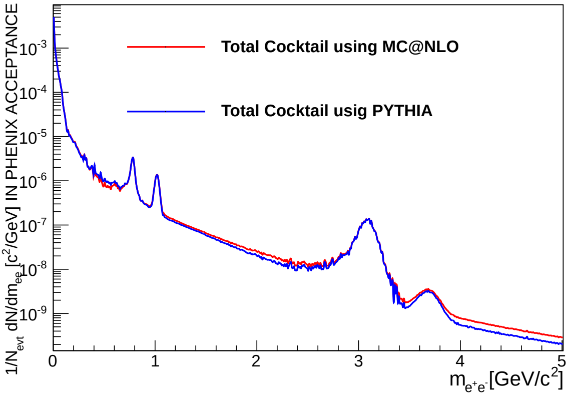
- Change in magnetic field configuration $\rightarrow$ change in acceptance
- Open heavy flavor shape from MC@NLO as event generation
  - For p+p, charm and beauty spectra from MC@NLO are adjusted to fit data.
  - For Au+Au, an additional N_{coll} scaling is applied for each centrality bin
- J/ψ line shape extracted from full detector MC

Effect of changes in cocktail simulation



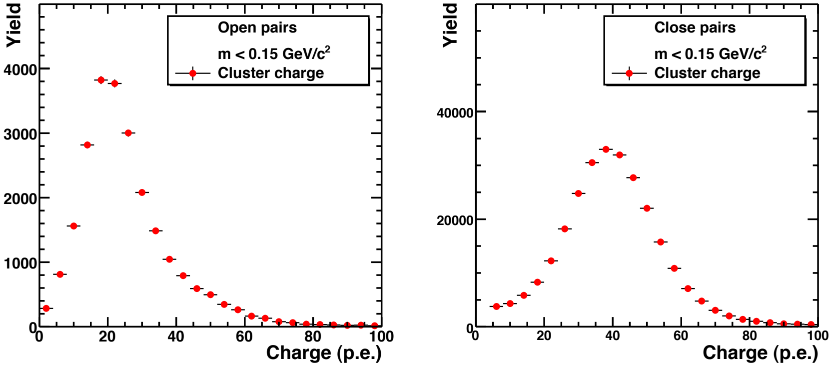
- Finite difference in pair acceptance between full field (++) and partial field (+-) configureations (HBD data was taken with (+-) field configuration)
- This difference in acceptance (shown in the mass projection above) should be accounted for in comparisons between HBD results and published phenix results.

Effect of changes in cocktail simulation



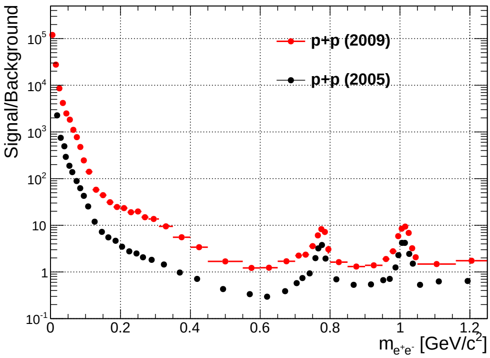
- Finite difference in total cocktail when using PYTHIA and MC@NLO as open heavy flavor event generator.
- Difference (on total cocktail) at IMR (1.2 GeV to 2.8 GeV) ≈ 16% and even lower at LMR

p+p Analysis: HBD performance



- Fully reconstructed π^0 Dalitz pairs ($m < 150\ MeV$) are split into two samples
  - Large opening angle ($>$ 100 mrad) - single signal amplitude ($\approx$20pe)
  - Small opening angle ($<$ 30 mrad) - double signal amplitude ($\approx$40pe)

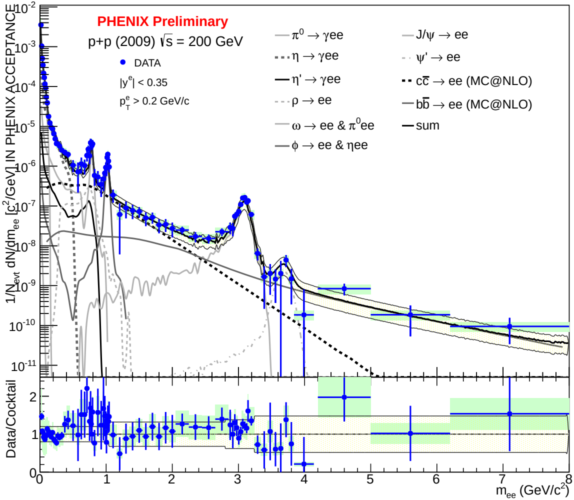
Poster 74, D. Sharma



- Factor ≈ x5 - x10 improvement in S/B in p+p
  - This improvement is achieved using the HBD just as another EID detector
  - More should be possible in p+p by using double rejection cut, but this is not the limiting systematic uncertainty in p+p results

p+p Result

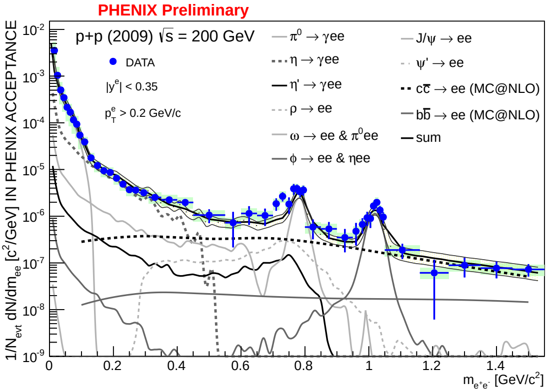
Poster 74, D. Sharma



- Excellent agreement between data and cocktail.

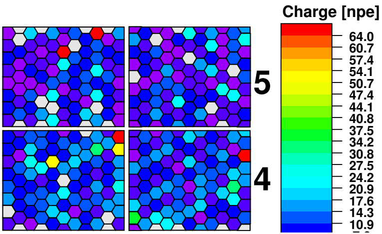
p+p Result

Poster 74, D. Sharma



- Excellent agreement between data and cocktail.
- Baseline for Au+Au analysis, as well as simpler environment to test understanding of the HBD detector subsystem

HBD in Au+Au collisions



- High Occupancy ≈100% in central events mostly due to scintillation in CF_4
- Mean single signal ≈20pe over 3 pads
- Mean background ≈10pe per pad highly fluctuating response to scintillation and curlers
- $\Longrightarrow$ High fake id rate

Event By Event BG Subtr.

- Stream A : Mean charge per pad calculated module by module in each event
- Stream B : Median charge per pad calculated for each track near the projection point

- Both Stream A and Stream B use track projection based cluster charge reconstruction and achieve compatible efficiency and rejection

Au+Au Results

- The results shown now for Au+Au are only for 20-40%, 40-60% and 60-92%

Analysis procedure

- Two independent analysis were performed to increase confidence in results
- The methods were substantially different in how they handled the HBD reconstruction, electron identification, single/double rejection and correlated background subtraction
- In both analyses, the combinatorial background is subtracted using mixed events. The difference is in how the correlated yield is handled

$$sig = UnlikeFG - Norm * MixedUnlikeBG - CorrelatedUnlike$$

Stream A

- HBD reco: Background subtracted using average charge per pad
- EID: Neural network for both Single/Double and electron identification
- Correlated dielectron background subtraction using acceptance corrected like sign

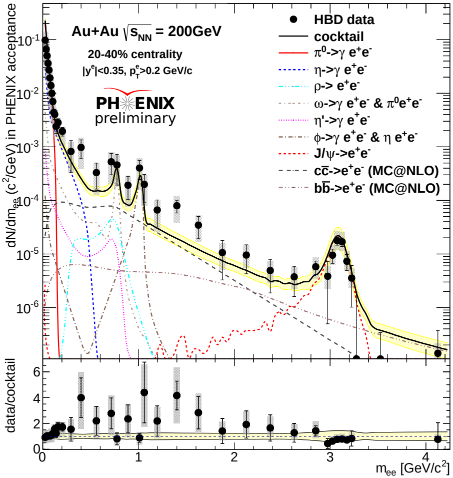
Stream B

- HBD reco: Background subtracted using track projection neighborhood
- EID: Standard 1D cut for both Single/Double and electron identification
- Correlated dielectron background subtraction using MC of cross pairs and jet pairs

- Stream A is used for comparison to cocktail because the PID procedure was superior. Stream B is used as a cross check.

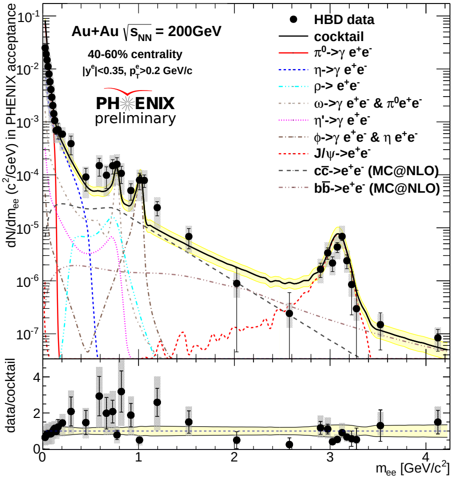
Au+Au Results, Centrality 20-40%

Plenary IVA, I. Tserruya



Au+Au Results, Centrality 40-60%

Plenary IVA, I. Tserruya



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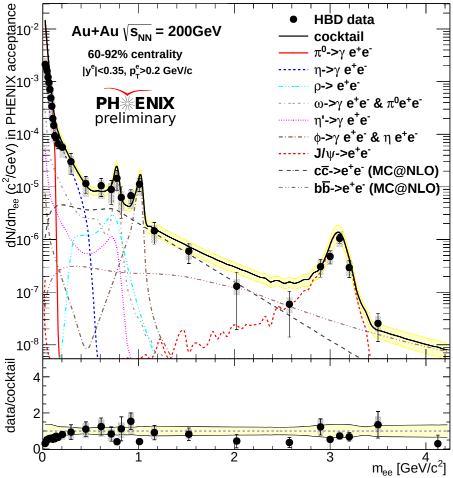
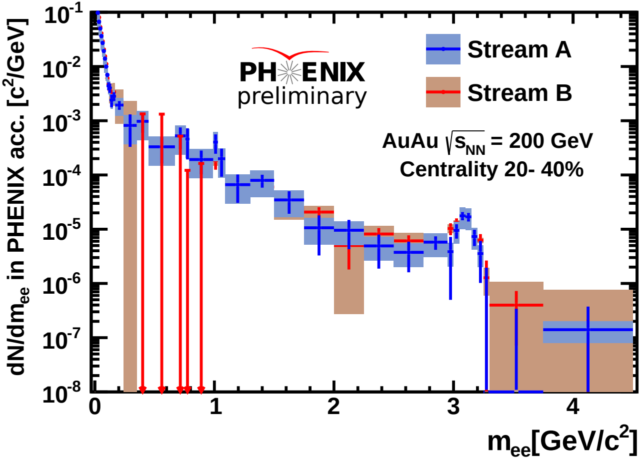
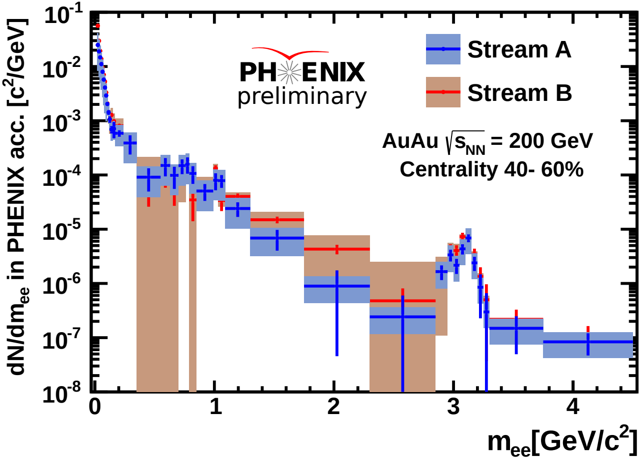


Poster 72, J. Sun



Au+Au Comparison of two analysis streams

Poster 72, J. Sun



Au+Au Comparison of two analysis streams

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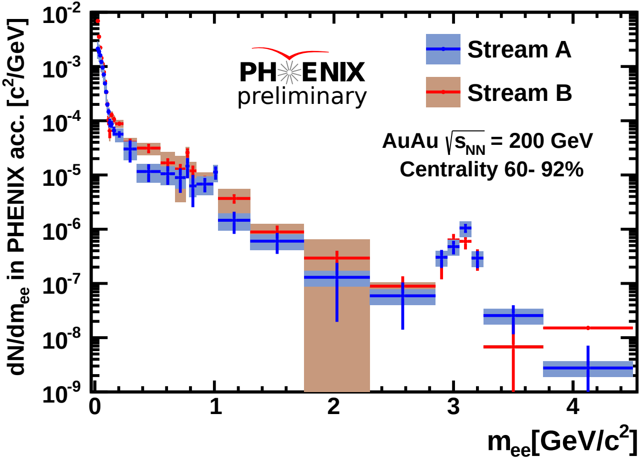
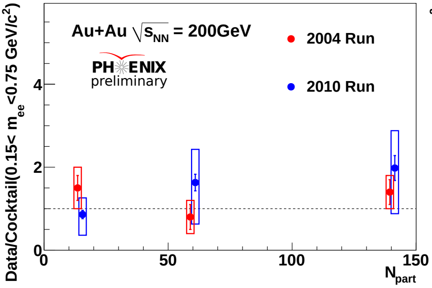
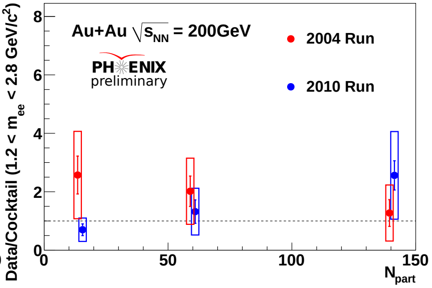


Compatibility with published results

Plenary IVA, I. Tserruya

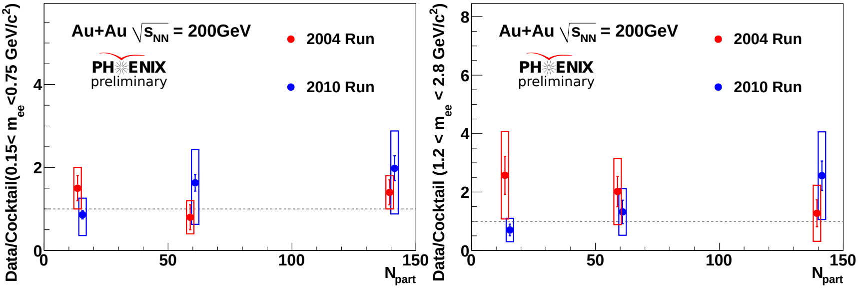




- The data/cocktail ratios comparison
  - The HBD analysis data/cocktail ratios are in agreement with the published result
  - Systematic uncertainties are dominated by conservatively estimated background subtraction errors

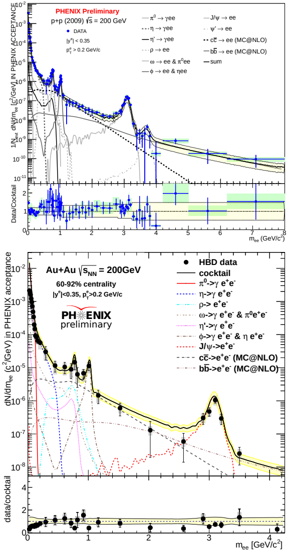
Compatibility with published results

Plenary IVA, I. Tserruya



- Opportunities for improvement
  - Extremely tight cuts and run QA used in the interest of uniformity that can be relaxed in future analyses
  - The dominant contribution to the systematics comes from the background subtraction method chosen. We expect improvement in systematic uncertainties from alternate subtraction methods

- The first dielectron spectrum results using the HBD are shown
- p+p results agree very well with the hadronic cocktail expectation
- The more peripheral Au+Au results also agree to within systematics with run 4 Au+Au analysis results
- In most central Au+Au, we are still refining the background subtraction method, stay tuned



Backup Slides

Change in Magnetic field (Acceptance)

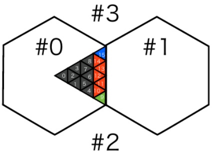
- Change in magnetic field configuration → change in acceptance

$$\phi_{min} \leq (\phi - \frac{q \times k_{DC}}{p_T}) \leq \phi_{max}$$

$$\phi_{min} \leq (\phi - \frac{q \times k_{RICH}}{p_T}) \leq \phi_{max}$$

- where $k_{DC} = 0.058$ and $k_{RICH} = 0.127$, with $\phi_{min} = -0.55$ and $\phi_{max} = 0.957$ for one arm and $\phi_{min} = 2.185$ and $\phi_{max} = 3.686$

1. Subtract the average charge per pad on event-by-event basis for each module
2. Decide which pad to use according to projection point



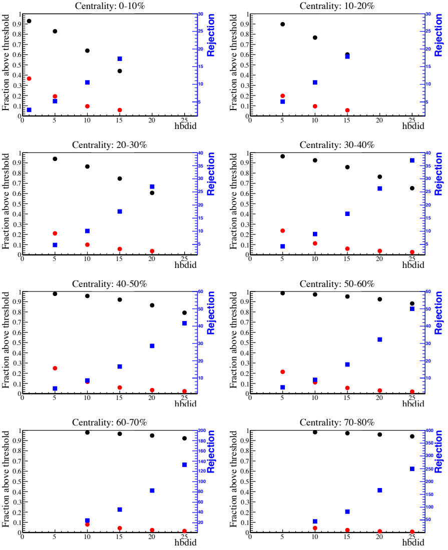
Expected cluster

Black:	#0
Red:	#0, #1
Green:	#0, #1, #2
Blue:	#0, #1, #3

This choice will be justified in slide 10

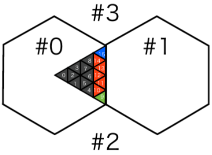
3. Calculate the total charge in the cluster

Plots to the right: efficiency for singles and rejection for back-plane conversions for all centralities in Au+Au events.



Performance in Au+Au collisions (Stream A)

1. Subtract the average charge per pad on event-by-event basis for each module
2. Decide which pad to use according to projection point



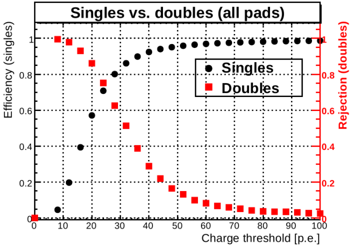
Expected cluster

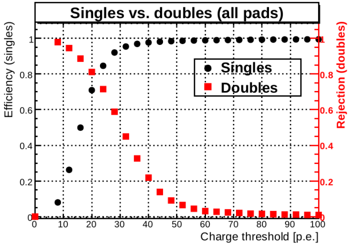
Black:	#0
Red:	#0, #1
Green:	#0, #1, #2
Blue:	#0, #1, #3

This choice will be justified in slide 10

3. Calculate the total charge in the cluster

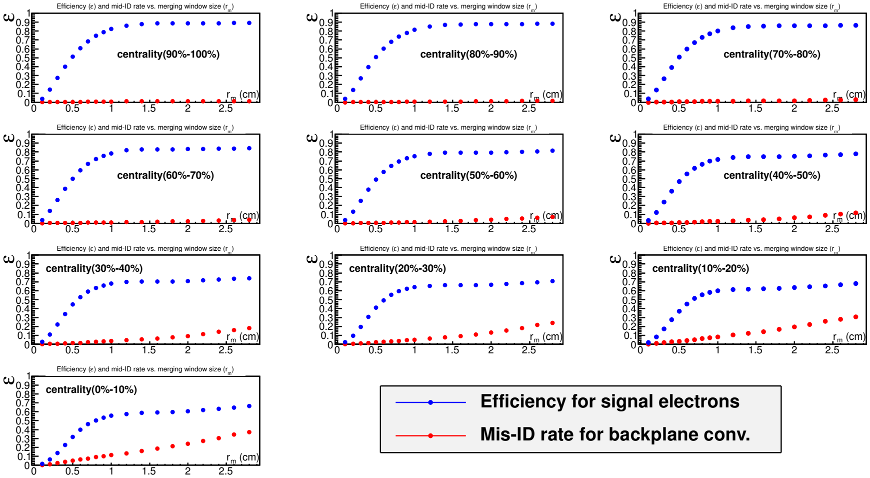
Plots to the right: efficiency for singles and rejection for double hits for centralities 0-10% (top) and 80-90% (bottom)





Performance in Au+Au collisions (Stream B)

- The SB reconstruction subtracts local background on triplets around track projections and merges all triplets with CG close to the track projection



LMR Excess

- Star also has a measurement in a somewhat different acceptance
- Star also observes low mass excess compared to expectation
- However there is disagreement in the amount of the excess seen by STAR and PHENIX
- Although some of it can be attributed to acceptance difference and systematic errors, it is very desirable to have another measurement with very different systematics